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	JOB:								--	
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TITLE: THERMAL SPRAY COATING APPLICATION OF ALUMINIUM

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1 INTRODUCTION

1.1 This Technical Specification establishes the minimum conditions required for thermally sprayed aluminum coating for corrosion control on offshore units to be executed according to AWS C2.23M/C2.23:2018.

1.2 The coating qualification of procedure, application and quality control shall meet AWS requirements, in addition to the changes indicated in the paragraphs of this technical specification.

2 NORMATIVE REFERENCES

All equipment shall comply with the requirements of this technical specification, data sheets, documents as stated below and with those referred to herein.

2.1 CODES AND STANDARDS

The following codes and standards include provisions which, through reference in this text, constitute provisions of this specification. The latest issue of the references shall be used unless otherwise agreed. Other recognized standards may be used, provided it can be shown that they meet or exceed the requirements of the standards referenced below.

- ASTM D4285 Standard Test Method for Indicating Oil or Water in Compressed Air.
- ASTM D4541 Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers.
- ASTM D4940 Standard Test Method for Conductimetric Analysis of Water Soluble Ionic Contamination of Blasting Abrasives.
- ASTM F22 Standard Test Method for Hydrophobic Surface Films by the Water-Break Test
- ISO 8501: Part 3 Preparation of steel substrates before application of paints and related products. - Visual assessment of surface cleanliness.
- ISO 8502: Parts 3, 6 and 9 Preparation of steel substrates before application of paints and related products. - Test for the assessment of surface cleanliness.
- ISO 8503: Parts 4 and 5 Preparation of steel substrates before application of paints and related products - Surface roughness characteristics of blast-cleaned steel substrates. - Part 5: Replica tape method for the determination of the surface profile - Second Edition
- ISO 9712 Non-destructive testing - Qualification and certification of personnel
- ISO 11126-7 Preparation of steel substrates before application of paint and related products - Specifications for non-metallic blast-cleaning abrasives. Part 7: Fused aluminum oxide.
- ISO 12690 Metallic and other inorganic coatings - Thermal spray coordination - Tasks and responsibilities - First Edition

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- ISO 12944-3 Paints and varnishes - Corrosion protection of steel structures by protective paint systems. Part 3: Design considerations.
- ISO 14917 Thermal spraying - Terminology, classification.
- ISO 14918 Thermal spraying - Approval testing of thermal sprayers.
- ISO 14919 Thermal spraying - Wires, rods and cords for flame and arc spraying - Classification - Technical supply conditions.
- NSF 61 Drinking water system components - Health effects.
- AWS C2.23M/C2.23:2018: Specification for the application of thermal spray coatings (metallizing) of aluminum, zinc, and their alloys and composites for the corrosion of steel¹.

Note (1): Also known as SSPC CS-23 and NACE N°12.

- SSPC-PA 2 Procedure for Determining Conformance to Dry Coating Thickness Requirements.
- SSPC-SP 1 Solvent Cleaning.
- SSPC-SP 5 White Metal Blast Cleaning.
- SSPC SP 11 Power Tool Cleaning to Bare Metal.
- SSPC-VIS 1 Guide and Reference Photographs for Steel Surfaces Prepared by Dry Abrasive Blast Cleaning.
- SSPC-TR 3 Dehumidification and Temperature Control During Surface Preparation, Application, and Curing for Coatings/Linings of Steel Tanks, Vessels, and Other Enclosed Areas.
- SSPC-AB 2 Cleanliness of Recycled Ferrous Metallic Abrasives

Governmental codes, regulations, ordinances or rules applicable to the equipment in Brazil shall prevail over the requirements of above specification, including reference codes and standards and/or these engineering specifications, only in those cases where they are more stringent.

2.2 REFERENCE DOCUMENTS

I-ET-3010.00-1200-940-P4X-002

GENERAL TECHNICAL TERMS

I-ET-3010.00-1200-970-P4X-003

REQUIREMENTS FOR PERSONNEL QUALIFICATION AND CERTIFICATION

3 DEFINITIONS AND ABBREVIATIONS

3.1 DEFINITIONS

In Addition of ISO 14917 is valid. Other definitions are:



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Spraying pass: The coat thickness deposited by the thermal spray coat process in one movement of the spray gun in one direction, without interrupting the movement.

Thermal spray coat layer: The coat thickness deposited by many overlapped spraying passes with no crossing pass.

Thermal spray coat thickness: The final thickness of thermal spray coating achieved by many designed layers of applied material over the surface.

3.2 ABBREVIATIONS:

TSC: Thermal spray coating;

JCR: Job control record;

QC: Quality control;

PDS: Product data sheet;

SENAI: Serviço Nacional de Aprendizagem Industrial

4 TSC FEEDSTOCK REQUIREMENTS

4.1 The feedstock material shall be Al 99.5 according to ISO 14919.

5 SURFACE FINISH REQUIREMENTS

5.1 PRIOR ACTIVITIES

5.1.1 Accessibility: The requirements of ISO 12944: Part 3 item 5.1 shall be considered before beginning the job.

5.1.2 JCR's shall be elaborated before beginning the works. The JCR's shall be available to the thermal sprayers and inspectors.

5.1.3 The preparation grades of welds, edges and other areas with surface imperfections shall be grade P3 of ISO 8501-3.

5.2 PRE-CLEANING

5.2.1 Immediately before spraying, the surface shall be dry and free from dust, grease, scale, rust and any contaminants.

5.2.2 The substrate shall be degreased according to SSPC-SP 1.

5.2.3 The surface shall be evaluated for Oil and Grease contamination. One test in each 250 m² or in any area suspected to have oil or grease contamination shall be performed.

5.2.3.1 Deionized or distilled water used in accordance with ASTM F22 shall be sprayed over the surface in thin. The area shall be representative of the total area to be painted. Proceed a



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visual inspection of the sprayed surface. If the sprayed surface is covered with a thin film of water, there is no oil or grease contamination. Otherwise, if water drops are formed over the surface, the oil and grease contamination shall be assumed.

5.2.4 The substrate may be hydro blasted (5000 - 10000 psi) to remove soluble salts contaminants before beginning the surface preparation.

5.2.5 Mechanical and Manual treatment, even power tool cleaning to bare metal in accordance with SSPC-SP 11, are not acceptable.

5.3 Abrasives:

5.3.1 Type: Use clean dry angular blasting abrasives. Unless otherwise specified, only aluminum oxide abrasives according to ISO 11126-7 shall be used.

5.3.2 Steel grit abrasives may be used but the following requirements shall be observed:

5.3.2.1 **BUYER** prior approval is required;

5.3.2.2 Before each reuse, the recyclable steel grit abrasive shall be cleaned of millscale, rust, paint, and other contaminants by an abrasive reclaimer;

5.3.2.3 At every work shift during blast cleaning operations, the Manufacturer shall verify that the recycled steel grit abrasives meet the requirements of SSPC-AB 2;

5.3.2.4 The abrasive material shall not be reused more than 3 times.

5.3.3 The absence of oil contamination shall be confirmed using the test for oil in the appropriate abrasive specification (no oil film or grease).

5.3.4 The soluble salts contamination analysis shall be done according to the appropriate abrasive specification. When it is not specified, the abrasive shall be tested according to ASTM D4940, and the maximum soluble salts content shall not exceed 100 μ S/cm.

5.4 Compressed Air:

5.4.1 All compressed air sources shall have oil and moisture separators, attached and functional, and properly designed and sized;

5.4.2 The compressed air sources shall deliver air to the blast nozzle, for blowing down the surfaces, or for conventional spray application that is free from oil and moisture and of sufficient pressure to accomplish the associated work efficiently and effectively;

5.4.3 The tanks on the air compressor and moisture separator shall be drained, at least, at the end of each work shift;

5.4.4 The compressed air source shall produce a minimum pressure of 90 psi at the nozzle during abrasive blast cleaning.

5.4.5 The compressed air shall be tested to verify the presence of oil and water according to ASTM D4285.

5.4.5.1 The test frequency shall be:

- a) Before the beginning of any work shift;
- b) 15 minutes after the beginning of the work shift;
- c) At least every four hours for each compressor system in operation.

5.5 Ambient Conditions:

5.5.1 No surface preparation shall be performed when the conditions are as follows:

- 5.5.1.1 When the relative humidity is above 85%;
- 5.5.1.2 When the substrate is damp or covered by frost or ice;
- 5.5.1.3 When the surface temperature is less than 5°C;
- 5.5.1.4 When the surface temperature of the steel is less than three (3) degrees Celsius above the dew point temperature as determined by a surface temperature thermometer and electric or sling psychrometer.

5.6 Soluble salts and Dust test:

5.6.1 The maximum acceptable water-soluble salts on abrasive blasted surfaces after surface preparation is 5 µg/cm² for carbon steel and 3 µg/cm² for stainless steels. The test shall be executed according to ISO 8502-6 or ISO 8502-9.

5.6.2 Before thermal spray application, the surface shall be dust tested in accordance with ISO 8502-3. The maximum acceptable is quantity: rating 2 for amount of particles; and dust size: rating 3 or over.

5.6.3 The minimum number of randomly taken measurements to be taken for verifying the dust or soluble salts on surfaces is given in TABLE 1. The number of measurements given is generally considered as being representative for inspection areas for the purposes of this standard. This number shall be increased for inspection areas having a difficult configuration with regard to paint application or measurement or limitations in accessibility (difficult areas).

TABLE 1 - SAMPLING PLAN FOR SOLUBLE SALTS AND DUST TESTS.

Sampling plan	
Thermal spray coated area (m ²)	Minimum number of measurements for soluble salts test
Up to 100	1
Above 100 to 250	2
Above 250	2 each 300 m ²

6 THERMAL SPRAY EQUIPMENT SETUP

6.1 The thermal spray equipment setup shall be stated at the TSC applicator's qualified procedure

7 JOB REFERENCE STANDARD (JRS)

7.1 General requirements

- 7.1.1 Any thermally spray coating procedure shall be qualified before starting the work.
- 7.1.2 Specimens to be tested shall be the same material specification as the equipment/ piping to be coated.
- 7.1.3 The procedure shall cover only one process and its operation (manual, automatic or mechanized).

7.2 Qualifying tests coupons.

7.2.1 TABLE 2 - 2 summarizes the test coupons and test to be performed during JRS.

TABLE 2 - TEST COUPONS

Test coupon	Dimensions (mm)	Coated face	Tests				
			Visual	Roughness	Thickness	Adhesion	Bending
Panel	500 x 500 x 3	One face	x	x	x	x	
Cantilever	FIGURE 1	One face	x	x	x		
Steel sheets tubular	1,25 x 50 x 75 ≤2" x 500 x 5	Width face Externally	x	x			5 coupons

7.2.1.1 The thermal spray coating thickness shall be between 200 µm to 400 µm;

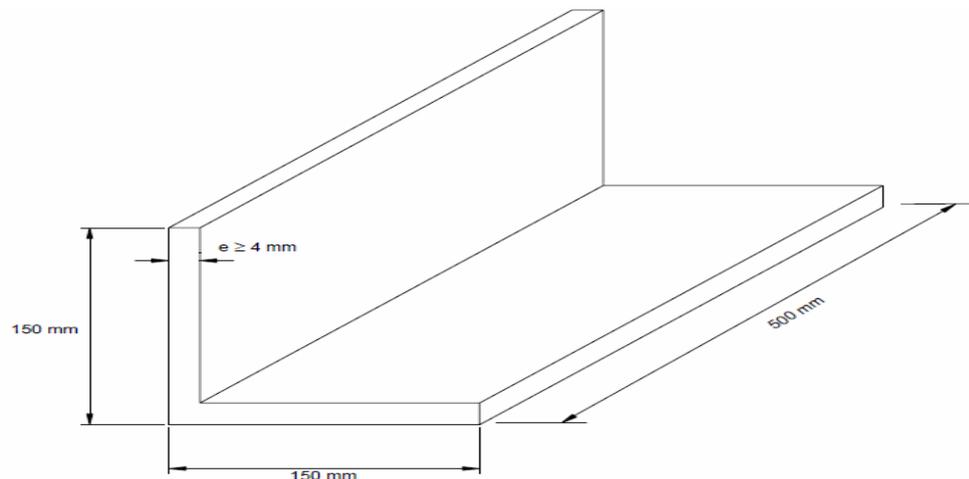


Figure 1 - Cantilever steel test panel.

7.2.2 Visual test:

7.2.2.1 The visual inspection shall be carried out in adequate light conditions. As a recommendation, a magnifier with 8-fold magnification may be used if necessary. The visual inspection shall be executed in the as-sprayed condition or after machining.

7.2.2.2 The thermally sprayed coated surface shall be smooth and uniform, without blisters or bare patches, cracks, loose particles or exposed material; and free from non-adhering metal and defects which can be detrimental to the service life and expected use of the protective coating.

7.2.3 Roughness test

7.2.3.1 The roughness shall be $\geq 65 \mu\text{m}$ with a sharp angular shape and a maximum of 120 µm.

7.2.3.2 The roughness shall have an angular profile and shall be measured using replica tape (replica tape) according to ISO 8503-5 or using the "Stylus" method by ISO 8503-4, considering the parameter RZ DIN or Ry5. The total roughness shall be obtained by three random measurements on the surface.

7.2.4 Thickness measurements:

7.2.4.1 Use type 2 electronic gage equipment according to SSPC-PA 2; The coating thickness is given as an arithmetical mean of at least three and preferably five individual measurements; Discard any unusually high or low gage measurement that cannot be repeated consistently.

7.2.4.2 Number of measurements:

- a) For steel sheet test panel: measurements along imaginary lines, each 80 mm distant from the others (see FIGURE 2);

- b) For cantilever steel test panel: measurements along imaginary lines, each 80 mm distant from the others (see FIGURE 3);
- c) For tubular steel test: four imaginary lines located at 90° from each other. (See FIGURE 4).

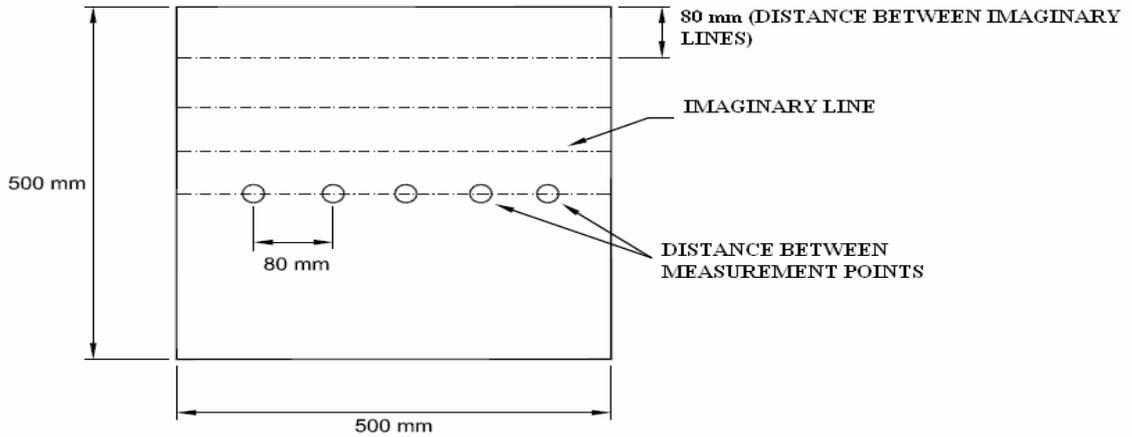


Figure 2 - Thickness measurements for steel sheet test panel.

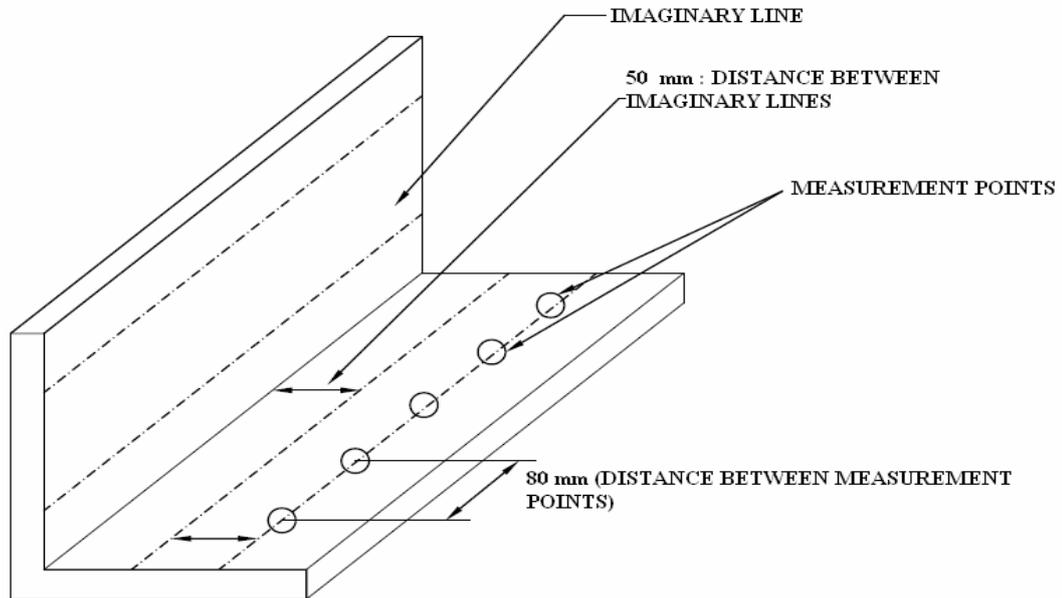


Figure 3 - Thickness measurements for cantilever steel test panel.

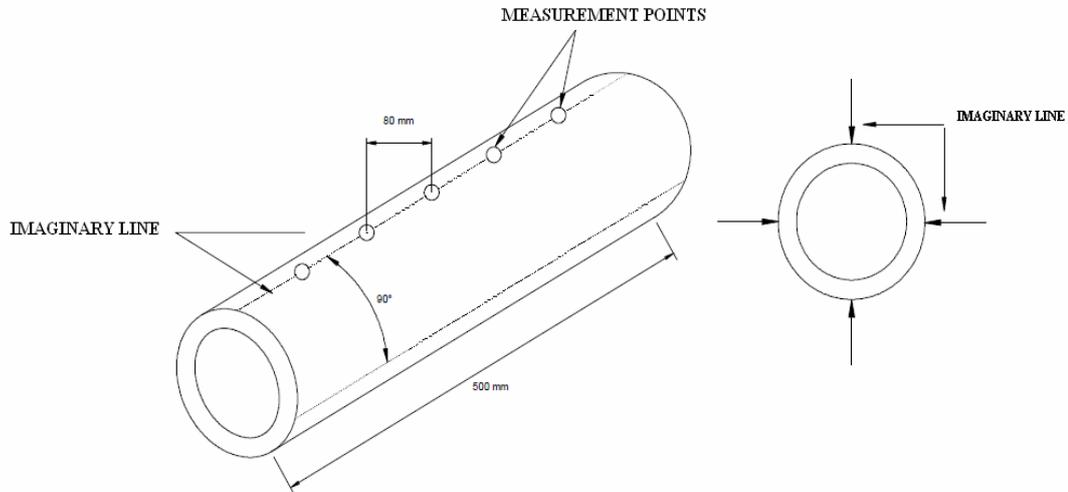


Figure 4 - Thickness measurements for tubular steel test.

7.2.4.3 Acceptance criteria:

- a) Minimum thickness: The average of the measurements shall be not less than the specified minimum thickness (TABLE 3). No single reading shall be less than 88% of the minimum.
- b) Maximum thickness: The average of the measurements shall be not more than the specified maximum thickness (TABLE 3). No single reading shall be more than 110% of the maximum.

TABLE 3 - REQUIRED THICKNESS FOR THERMAL SPRAYED ALUMINUM COATINGS.

Minimum Thickness	Maximum Thickness
200 μm	400 μm ⁽¹⁾

 (1) Thickness higher than 400 μm but lower than 450 μm is considered acceptable if approved in the adhesion test.

7.2.5 Adhesion measurements:

7.2.5.1 Test equipment according to ASTM D 4541, using pneumatic adhesion tensile testing instrument with an automatic centered pulling force and self-alignment;

7.2.5.2 Adhesion test locations shall be according to FIGURES 5

7.2.5.3 The average of the measurements shall be not less than 10 MPa. No single measurement shall be less than 7 MPa.

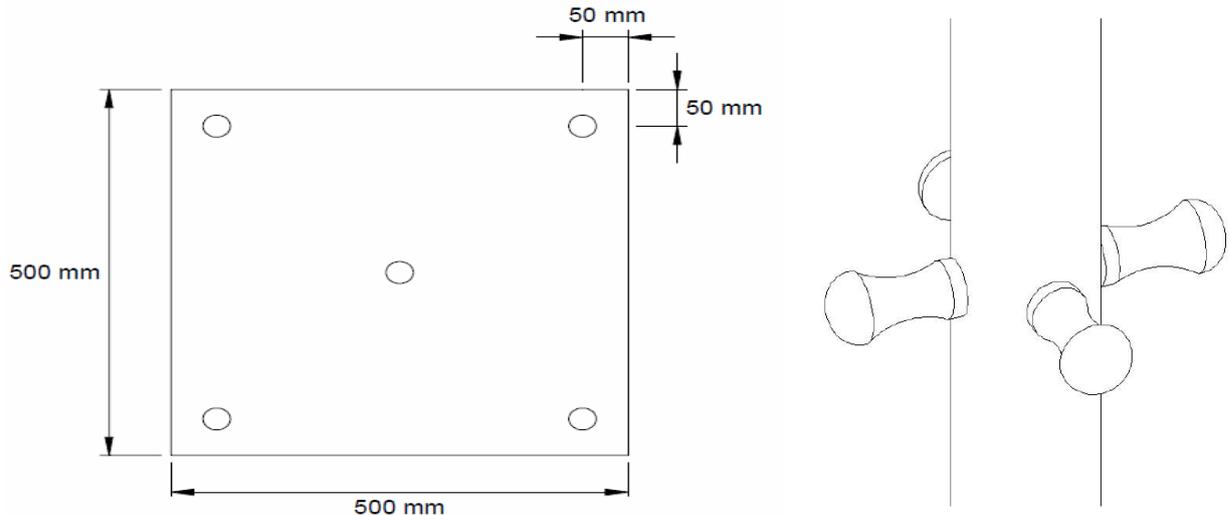


Figure 5 - Adhesion measurement points location.

7.2.6 Bend test:

7.2.6.1 Bend test is mandatory for JCR and shall be performed in accordance with ANNEX A of AWS C2.23M/C2.23:2018.

7.2.6.2 Bend test equipment shall have a mandrel with a diameter of 13 mm.

7.2.6.3 Bend test passes if on the bend radius there is no cracking or detachment or there is only minor cracking that cannot be lifted from the substrate with a knife blade.

7.3 Report of qualification tests:

7.3.1 The qualification test report shall contain, at least, the following information:

- a) Data of issue;
- b) Report number or code;
- c) Thermal spray coating procedure evaluated;
- d) Identification of the entity responsible for performing tests;
- e) Responsible for performing the tests;
- f) Thermal spray coating system information regarding surface preparation and application;
- g) Information about consumables (metallic material and abrasives) as: the name of the manufacturer, chemical composition, size (for abrasives only) and batch number;
- h) Test results;
- i) Conclusion;
- j) Standards used during tests.

8 TSC APPLICATION PROCEDURE

8.1 Thermal spray process:

8.1.1 The thermal spray process acceptable is ARC spraying processes. Flame spraying process requires previous approval by **BUYER**.



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8.2 Thermal spray coating thickness:

8.2.1 For edges and corners: between 200 to 300 μm ;

8.2.2 Other cases: between 200 to 400 μm .

8.3 Holding period:

8.3.1 between the completion of the final surface preparation and the completion of the thermal spraying shall be no greater than six hours for steel substrates with the following exceptions; The time between the completion of the final surface preparation and the completion of the thermal spray coat flash coat shall be no greater than two hours for steel substrates.

8.3.2 For steel tanks, vessels and other enclosed spaces which have an environmental control according to SSPC-TR 3/NACE 6A192, it may be possible to retard the oxidation of the steel and hold the surface finish for more than six hours. The TSC applicator, with the previous approval of **BUYER**, may establish a holding period greater than six hours by determining the acceptable temperature-humidity envelope for the work enclosure by spraying and analyzing bend coupons, tensile-bond specimens, or both.

8.3.2.1 The following method shall be used for bend-test coupons: (a) establish, measure, and record the low-humidity environment; (b) prepare four bend test coupons according to contract specifications; (c) place bend-test coupons in the low-humidity environment; (d) after target holding period duration, apply the contact specified thermal spray coating; (e) perform the bend test (f) the low-humidity environment and holding period are satisfactory if the four test bend coupons meet the requirement



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8.4 Thermal spraying

8.4.1 Thermal spraying shall be carried out in uniform passes (of the same width) and with overlapping 1/3 to 1/2 of the pass to ensure uniformity of coverage

8.4.2 The layers (at least two layers) should be crossed and the passes applied always as possible in the feet / head / feet and left / right / left directions. The pass thickness shall be kept as thin as possible in order to increase grip and cohesion between layers

9 INSPECTION OF APPLIED TSC

9.1 Thickness measurements:

9.1.1 Minimum Thickness: The average of the acceptable gage readings shall be no less than the specified minimum thickness (TABLE 3). No single gage reading shall be less than 88% of the minimum;

9.1.2 Maximum thickness: The average of the acceptable gage readings shall be no more than the specified maximum thickness (TABLE 3). No single gage reading shall be more than 110% of the maximum.

9.1.3 If the TSC thickness is greater than 400 μm but lower than 450 μm , information shall be recorded in the JCR and one adhesion test shall be done at every 1 m^2 of over thickness area. If the results of adhesion tests fail, all over thickness areas shall be re-blasted and the TSC coating reapplied; if the results of adhesion tests pass, the inspector shall record the adhesion value.

9.1.4 Frequency of measurement:

9.1.4.1 For TSC areas under 1 m^2 : one measure in line.

9.1.4.2 For TSC areas over 1 m^2 but under 10 m^2 : One measurement after the first square meter and others after each 2 m^2 of applied TSC.

9.1.4.3 For TSC areas over 10 m^2 : One measurement shall be taken every 10 m^2 of applied TSC for flat surfaces. For complex surfaces one measurement shall be taken every 5 m^2 of applied TSC. Each measurement shall be the average value of five readings.

9.2 Tensile Adhesion:

9.2.1 The TSC tensile bond shall be measured according to ASTM D4541 using a self-aligning adhesion tester, method D - Equipment Type IV and Method E - Equipment Type V- with automatic actuation.

9.2.2 One portable tensile-bond measurement shall be made every 20 m^2 . If the tensile bond is less than the contract specification, the degraded TSC shall be removed and reapplied.

9.2.3 For nondestructive measurement: Tensile force shall be measured up to 10 MPa. The tensile force shall then be reduced, and the tensile fixture removed without damaging the TSC.

9.3 Bend Test

9.3.1 Bend test is mandatory and shall be performed in accordance with ANNEX A of AWS C2.23M. The test shall be performed before start of each shift.



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10 APPLICATION OF SEALERS AND TOPCOATS

10.1 The thermal sprayed steel shall be sealed and not be painted. No topcoat is required.

10.2 Sealing shall be carried out preferably as soon as the substrate temperature is close to 60 °C for the application of the sealant or in a maximum time of 24 h after the end of the application of aluminum -based coatings.

10.3 The Table 4 shall be followed for selection of sealant.

Table 4 - Specification of sealers

Environmental condition	properties	Sealant material
External Atmospheric Corrosion without / with Immersion, Operation up to 93 ° C Continuous or with Peak Temperature up to 120 ° C Maximum	Dry film thickness 25 - 35 µm Paint dilution - Dilution level and solvent indicated by the manufacturer for obtaining the specified thickness	Epoxy paint cured with polyamine or polyamide with LOW VOCs (Content of Volatile Organic) (Note 1). Maximum operating temperatures shall be guaranteed by the manufacturer presented in the respective technical product datasheet.
External Atmospheric Corrosion with Maximum Operating Temperature between 120 °C and 500 °C	Dry film thickness 25 - 35 µm Paint dilution - Dilution level and solvent indicated by the manufacturer for obtaining the specified thickness	Silicone resin based paint curable at room temperature with solids content by volume in the range of 30 to 50% and viscosity in the range of 50 to 70 UK (Krebs Stormer) or CF # 4 (Ford Cup 4) 15 to 35 s. Maximum operating temperatures shall be guaranteed by the manufacturer presented in the respective technical product datasheet.

Note 1: Low VOCs are paints with a volatile content of less than 250 g / l or whatever required by applicable environmental legislation.

10.4 For Fresh Water or Potable Water services sealants may not be used. If required, the sealant shall be certified according to NSF 61.

11 RECORDS

11.1 The TSC applicator shall use a JCR to record the production and QC information and other information required by the purchasing contract. Additionally, the TSC applicator shall have its own Quality Assurance Program. The TSC applicator shall keep records for a time period consistent with the TSC applicator's quality assurance and records program and as required for regulatory compliance and the purchasing contract. Records shall be stored for a minimum of five years.

11.2 QUALITY CONTROL

11.2.1 The **SELLER** shall have as many Job Control Records as necessary to do the Job. Those documents shall be available to thermal spray team at any time.

11.2.2 The **SELLER** shall have a thermal spray coating inspector to perform the tests and elaborate the quality control inspections and reports.



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11.2.3 **SELLER** QC inspections shall include, but not limited to the following:

- a) Pre surface Preparation Inspection (Design conditions, presence of oil and grease);
- b) Ambient conditions (prior to blasting, during blasting works, and during the thermal spray coating works);
- c) Compressed air cleanliness (during blasting and thermal spray works);
- d) TSC feedstock material quality;
- e) Abrasive cleanliness and quality;
- f) Surface preparation (presence of oil and grease, content of soluble salts, surface cleaning standard and surface profile);
- g) Thermal spray coating application (Equipment setup, holding times, etc.);
- h) Thermal spray coating quality (thickness, adhesion, appearance of the applied coating, etc.);
- i) Sealer coating quality (dry film thickness).

11.2.4 After any thermal spray coating work a report shall be done. The report shall have, but not be limited to, information data about:

- a) Manufacturer data (company name and contract number);
- b) Issuing data;
- c) Thermal spray process used;
- d) Thermal spray procedure (codification number);
- e) Substrate related: Codification of the equipment or component thermally sprayed; Surface areas coated; Surface profile; Presence of oil and grease; soluble salts content; Surface cleanliness according to SSPC-SP VIS 1.
- f) Ambient conditions: Humidity; Surface temperature; Surface dew point temperature; Air temperature.
- g) Compressed air: Presence of oil and water; Air pressure.
- h) Abrasives: type; Cleanness; Size; Presence of oil and water.
- i) Thermal spray coat: Thickness; Adhesion; Feedstock quality; Holding times.

12 DEBRIS CONTAINMENT AND CONTROL

Debris containment and control shall be according to AWC 23.00, Section 11.

13 WORK PROCEDURES AND SAFETY

Work procedures and safety shall be according to AWC 23.00, Section 12.



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14 APPLICATION PROCEDURE

14.1 The thermally spray coating application procedure shall contain, at least, the following information:

- a) Scope of the work;
- b) Personnel certification and qualification requirements;
- c) Thermal spray processes employed;
- d) Pre-cleaning process (when necessary);
- e) Surface preparation method;
- f) Safety and environmental requirements;
- g) Quality control points (in process, and hold points);
- h) Inspection equipment;
- i) List of all equipment;
- j) Calibration procedures and reports.

15 PERSONNAL AND TSA APLICATOR QUALIFICATION

15.1 Qualification and certification shall be in accordance with I-ET-3010.00-1200-970-P4X-003-REQUIREMENTS FOR PERSONNEL QUALIFICATION AND CERTIFICATION.